THE TUNAS OF THE GENUS *THUNNUS* IN SOUTH AFRICAN WATERS.

PART I. INTRODUCTION, SYSTEMATICS, DISTRIBUTION AND MIGRATIONS

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(With 8 figures)

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Introduction

In South Africa research on the tunas lagged far behind that in European countries, the Americas, and especially Japan. Prior to 1945 tunas were considered by ichthyologists to be only rare migrants to South Africa.

Tunas were first recorded from South Africa by Günther (1860). Other early records were those of Gilchrist (1902) and Thompson (1918), and later Barnard (1927), Biden (1930), Smith (1935) and Barnard (1939). All considered tunas to be rare in South Africa; only Biden suggested that they might be present in greater quantities than indicated by the records.

In March 1941, tuna were reported to be common in False Bay (newspaper reports), but the species was not identified. In December 1945, large numbers of tuna reported to be small *Thunnus thynnus* (newspaper reports in which the fishes were stated to have been identified by Molteno) were caught from the shore near Cape Point, False Bay. Sport fishing recovered after the war, and by 1952 fishing for tuna off the Cape Peninsula was firmly established. Several thousands of troll-caught tuna were being landed each summer season. Up to

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1960 there was no commercial exploitation (Talbot & Penrith, 1960).

At the time of the beginning of the present survey (1960) the possibility of subsurface populations being present was not known, tuna were thought to be absent from the Cape in winter, and nothing was known of their biology from this area. Molteno (1948) had published a useful list of species known and to be expected from South Africa, with biological data based on work in other parts of the world, and Smith (1949) considered the species known at that time, giving a key for their identification in his treatise on South African marine fishes.

The present survey was conducted in two parts, as an eighteen-month survey in the south-western Cape (1960–1) and a two-month survey in the south-western Indian ocean (August 1962; February 1963). A ship, crew, and equipment were supplied by Irvin & Johnson Ltd. for the Cape survey, and by the South African Navy and the South African Council for Scientific and Industrial Research for the Indian ocean. Scientists were supplied by the South African Museum and the Council for Scientific and Industrial Research. It was decided that of the four possible methods for obtaining tuna samples (surface trolling, pole-and-line fishing, long-lining, and purse seining) only long-lining would be used, as this method required the least ship modification.

Aims of the survey

It was decided that priority should be given to the following problems, which were considered to be of particular interest:

(*a*) Systematics. In 1960 the taxonomy of tuna throughout the world was very confused; for example, the Atlantic and Indo-Pacific yellowfin, which were indistinguishable when placed side by side, were put in different genera. This was the case with many of the tunas, and matters had reached such a point, where, for clarity, the common names were being used rather than the scientific. It was felt that specimens from the Cape, being situated at the boundary between the Indo-Pacific and Atlantic oceans, could be of value in solving some of these systematic problems.

(*b*) Distribution. As three very different water masses meet at the Cape, attention was aimed at local distribution, and the relationship between distribution and hydrographic factors.

(*c*) Feeding. Practically nothing was known about feeding of tuna in South African waters. Troll-caught tuna fed mainly on pilchards (*Sardinops ocellata*) and squid (*Loligo reynaudi*) (personal observations) and the only published statements were by Horne (1959) on the finding of a grunter (*Pomadasys operculare* Playfair) in the stomach of a large *Thunnus thynnus* netted in False Bay. There was no knowledge of possible food preferences and competition between species in this area.

(*d*) Breeding. Nothing was known about the breeding of the tuna found off South Africa. The breeding times and size of maturity were unknown; it was not even known whether tuna did breed in South African waters. From the findings of sports fishermen it was assumed that the tuna left to breed elsewhere

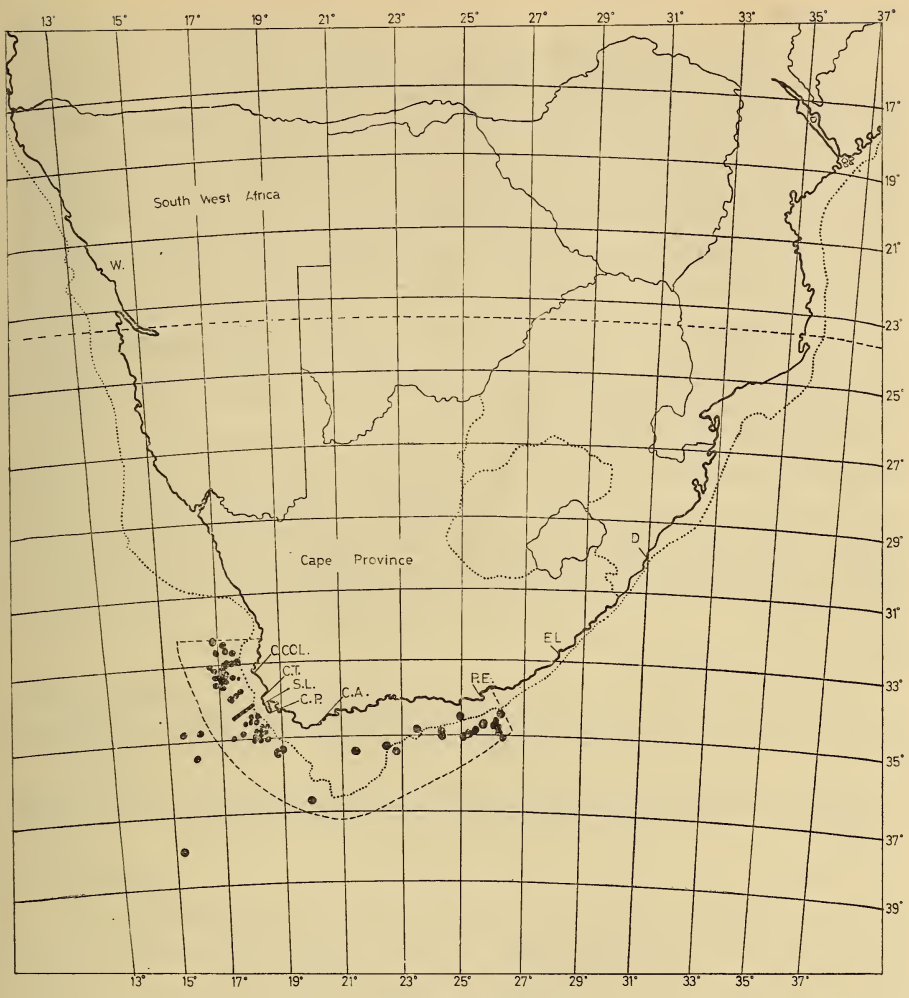


Fig. 1. Area of survey. Each dot represents one station, except off Slangkop, Cape Peninsula, where the solid line represents 51 stations.

during the southern winter (May–September), as no tuna were caught during these months. It was hoped that detailed examination of the gonads could give give some indication of when the breeding period occurred, and possibly whether breeding took place locally or not.

(*e*) Age and growth. It was proposed to use the length frequency method of determining growth, and to examine scales or some part of the skeleton (e.g. otoliths or vertebrae) in an attempt to find growth rings which could be correlated with any modes found in the length frequency curves.

The results bearing on (*a*) and (*b*) above are reported on in this paper.

Area of study

It was decided that, rather than cover a wide area in an overall search for subsurface fishes, it would be more valuable to concentrate the survey in one area, so that any changes during the year would be more comparable. The survey was concentrated in a line running out magnetic west from Slangkop for two reasons: firstly, surface tuna were known to occur in the area in large numbers at certain times of the year (Horne, 1954), and secondly, the University of Cape Town research vessel *John D. Gilchrist* had a monthly series of hydrographic and plankton stations on the same line. It was also known that sudden changes in surface temperature occur along this line, a factor widely known as a good indicator for tuna (Thompson, 1917; Powell *et al.*, 1952; Murphy & Shomura, 1955). Figure 1 is a map of the area surveyed, indicating the stations at which long-lines were fished.

Sixteen cruises of between four and fifteen days' duration were made. During four of the cruises fishing was undertaken off the east coast, but on all four occasions the fishing was severely hampered by storms. In addition to these cruises, two cruises, each of a month, were made in the south-west Indian Ocean, one in summer and one in winter. A complete list of stations is given in Appendix A.

Description of methods used

One basket of gear with components and lengths is sketched in figure 2. Each basket was 200 fathoms long. 8 mm Kuralon was used for the main line

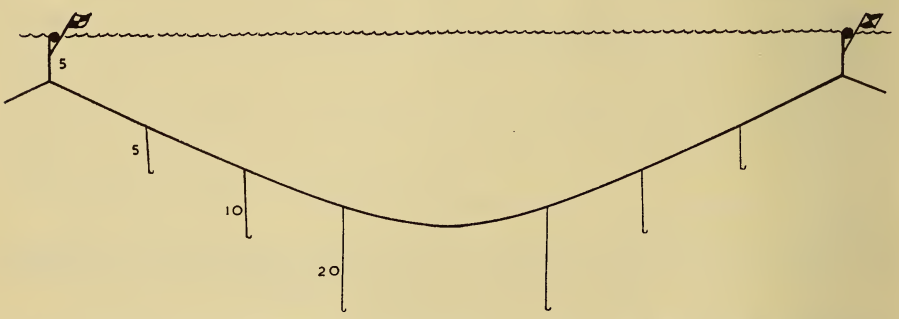


Fig. 2. Diagrammatic representation of one basket of long-line as used in the present survey. Lengths in fathoms.

and droppers. In order to study depth distribution the normal catenary curve of the line was accentuated by keeping the outer droppers short, and lengthening the middle droppers.

Setting was begun before dawn (5.00–6.30 hours) throughout the year, as tuna seem to be mainly dawn and dusk feeders (Nakamura, 1949; Powell, 1950; Powell *et al.*, 1952). Bait used was whole pilchards (*Sardinops ocellata*), frozen or lightly salted. Usually twenty baskets of long-line were set at a time,

this taking some forty minutes.

At the completion of setting, a bathythermograph cast was made, water samples and temperatures taken. Three water samples and temperatures were made, at 0, 30 and 150 metres, using a Petterson-Nansen insulated bottle fitted with a Negretti and Zambra thermometer. The two subsurface depths were chosen as being at above the level of the shallowest and deepest hooks. Salinity determinations were made by the Division of Sea Fisheries using a salinometer. Hauling of the long-line was done at about 10.30 a.m., after the line had been in the water for about 4–5 hours. The condition of each hook was listed as it was hauled (baited, no bait, fish).

Immediately after completion of hauling the fish were all washed, spread out on the deck, and the identification in the hook log checked. The fork-length of all fish was then measured using a 2·5 metre long pair of calipers, and morphometric measurements according to the method of Marr & Schaefer (1949) were made on as many fish as possible. Measurements other than fork-length were not made on albacore (*T. alalunga*).*

The gonads and stomach contents of all fish (other than shark-damaged specimens) were removed and preserved. Formalin of 10% strength was used so as to stop the process of digestion as rapidly as possible and to harden the forage organisms which had become soft due to digestion.

Notes on sampling

Selectivity

No fishing gear is completely unselective, and the long-line is no exception. The factors that might influence selection are discussed below.

(*a*) Hook size

The Japanese hook (size 3, 6 cm high, 3 cm wide) was chosen because it was the middle of the size range offered. It was found, however, that hook size is only of minor importance, as tuna from 5 to 400 lb were landed, as well as other larger fish which had much larger mouths than any tuna (large sharks, e.g. *Prionace glauca* and marlins, *Makaira* spp., of up to 1,460 lb), and exceptionally small-mouthed fishes such as *Brama raii* and a pilot fish *Naucrates ductor* weighing less than 1 lb. It is not possible to disprove selection due to hook size, but the wide size range of fishes taken suggests it was not a major factor.

(*b*) Sampling depth

There was a very marked selection due to the sampling depth. Surface trolling by game-fishing vessels off the Cape Peninsula results in a catch consisting almost exclusively of yellowfin tuna (*T. albacares*), whereas in the survey *T. albacares* accounted for only 11·6% of the total tuna catch, and in the Cape

* In South Africa *T. alalunga* has the common name longfin tuna. The name albacore is used for the carangid *Seriola lalandii*.

Peninsula area 8·8%. Conversely, the long-line took large numbers of other tuna species that had only rarely been taken by surface trolling. This makes it difficult to attempt to assess the true relative abundance of the various species, but subsurface long-lining did capture fair numbers of four species, whereas surface trolling or pole-and-line fishing could be expected to take only two species. Long-lining also in general captures larger fish than surface trolling; *T. alalunga* of over 950 mm fork-length are rare using the latter method but are commonly taken on long-lines. Presumably this is due to swimming depth of various sizes of tunas.

(*c*) Hunger and seasonal feeding changes

By its nature a baited line will normally only take feeding fish. Sampling error caused by this, and possibly also by seasonal changes in food requirements, could not be assessed.

Faults and advantages of the sampling method used

The major fault of long-lines for obtaining samples of tuna is that only the subsurface populations are sampled. Surface trolling has shown much larger populations of *T. albacares* in the area surveyed than the results from the long-lining.

Another disadvantage was the lack of any knowledge of actual depth of capture. The work of Kamimura (1957) has suggested that most tuna are caught at a depth shallower than the maximum to which the hook sinks. It was not known in the present survey exactly how deeply the hooks did sink. Some workers, especially at the U.S. Bureau of Commercial Fisheries at Hawaii, used a rangefinder or radar to measure the distance between the buoys and, knowing the length of the line between them, could calculate the catenary of the line. This, however, does not take into consideration the effects of bowing or slanting of the line due to subsurface currents or the action of hooked fish. It was planned to attach Kelvin sounding tubes to certain of the droppers to find the catenary of the line, but their use was discontinued owing to the very contradictory results obtained (see also Murphy & Shomura, 1953). Graham & Stewart (1958) have shown that the line may go deeper during hauling than it normally hangs. Attempts to locate the line by means of echo-sounding were unsuccessful. On one occasion off Port Elizabeth several of the hooks did touch the bottom, bringing up bits of coral, from 78 to 80 fathoms, showing that the deepest hooks at least reach this depth.

It was assumed that the outside hooks of the basket with 5-fathom droppers fished at 15–20 fathoms, the 10-fathom droppers at 35–45 fathoms, and the long centre dropper of 20 fathoms at 75–80 fathoms.

In general it can be stated that the long-line, in spite of the above disadvantages, is probably the best method of estimating the abundance and size-range of large subsurface fishes.

Systematics

Starks (1910) was the first to notice the presence of a prootic pit in the skull of certain of the Scombridae, and proposed the subfamily Thunninae to contain the genera *Thunnus*, *Auxis*, *Katsuwonus* and *Euthynnus*, which possessed it. Kishinouye (1923), after his careful anatomical studies on the Scombridae, on the basis of the prootic pit and the subcutaneous blood system which he found to be present in the fishes contained in Starks's Thunninae, proposed that these four genera (much subdivided by him), should be separated into the order Plecostei, having equal rank with the order Teleostei, which would contain all the other bony fishes. It is perhaps best to consider Kishinouye's work as a brilliant monograph on scombrid anatomy, but to ignore the final section on classification. Berg (1940) in his definitive work unfortunately leaned heavily on Kishinouye. Berg's order Thunniformes (being Kishinouye's Plecostei) is removed from the suborder Scombroidei in the order Perciformes. This step is not quite so drastic as that proposed by Kishinouye, but any attempt to separate the tunas and mackerels into even separate families does not seem warranted.

Since 1950 several reviews of the Scombridae have appeared. Fraser-Brunner (1950) proposed a straightforward classification, having two subfamilies, Gastrochismatinae and Scombrinae, and sinking many of Kishinouye's genera to subgeneric level. Ginsburg (1953) and Godsil (1954) agreed with Fraser-Brunner that the Thunniformes and Scombroidei (of Berg) were so closely related that they should be kept in one family. This has been done also by Collette & Gibbs (1963*a*, 1963*b*), and has been followed here.

Many generic names have been suggested for the large tunas, and *T. alalunga*, *T. obesus*, *T. albacares* and *T. tonggol* have all been placed in monotypic genera at various times. Most authors now consider that the genera *Germo*, *Neothunnus*, *Kishinoella* and *Parathunnus* should be dropped (Fraser-Brunner, 1950; Ginsburg, 1953; Godsil, 1954; De Sylva, 1955; Collette & Gibbs, 1963*a*) but the names have remained in general use because they were the names used by many tuna biologists in Japan and the United States. There are a number of reasons for placing all the large tunas in a single genus, the main one being the arbitrary nature of any divisions within the group, depending upon what characters are used. The following choices of grouping indicate this. Watson (1963) has shown on the basis of osteology that there can be two groups, *T. obesus* being similar to *T. thynnus* and *T. alalunga*, while *T. albacares* is similar to *T. tonggol* and *T. atlanticus*. De Sylva has suggested, also on the basis of osteology, that *T. albacares* and *T. obesus* are closely related. Beebe & Tee-Van (1936) claimed on the basis of external morphology that *T. obesus* and *T. atlanticus* are closely related. This indicates that such groupings give little information on the phyletic history of the tunas. A single genus with several species seems the best arrangement of the group.

Genus THUNNUS South, 1845

Description: Body robust; abdomen without median groove for pelvic fins; adults with body completely scaled, anterior scales larger, forming a corselet; juveniles not necessarily fully scaled (Moore, 1951); interpelvic process bifid; teeth small, conical, in a single row in each jaw; vomer and palatines toothed; no strongly developed adipose eyelids; well developed lateral keel on each side of caudal peduncle and two smaller keels on tail above and below hind end of larger keel; gill-rakers 20–42 (both arches); dorsal fins almost contiguous; dorsal spines 13–15, rays 22–23, some posterior rays separated as separate finlets; anal rays 21–22, with posterior finlets as in dorsal; vertebrae 39, first reduced and firmly articulated to the skull; well developed subcutaneous blood-vessels on sides; skull with deep prootic pits.

The number of species in the genus is still in some doubt (Rivas, 1961; Roedel & Fitch, 1961) but a number of authors such as Collette (1961), Collette & Gibbs (1963*a*), Mather (1963*a*), and Watson (1963) consider that there are six species. Here we provisionally recognize seven species, of which five occur in South Africa waters.

Thunnus albacares (Bonnaterre)

Yellowfin

Scomber albacares Bonnaterre, 1788:140.
Neothunnus itosibi: Smith, 1935:207. Molteno, 1948:33.
Germo albacora: Molteno, 1948:20. Smith, 1949:299.
Germo itosibi: Smith, 1949:299.
Thunnus albacares: Talbot & Penrith, 1960:1, 1961*a*:1, 1962:558, 1963*a*:617. Talbot, 1964:205. De Jager, 1963:589. De Jager *et al.*, 1963:11.

Liver without striations on its ventral surface, and with the right lobe longer than the central and left lobes. Pectoral fins long, reaching to or beyond the origin of the soft dorsal except in large individuals. Dorsal and anal lobes exhibiting marked allometric growth and becoming extremely elongated in large specimens, reaching even beyond the caudal fin. Gill-rakers 11 + 19–20. (See table 1, for morphometric data.) Swim bladder present. A dense rod of connective tissue running down the dorsal wall of the body cavity presses into

	Thunnus albacares					
Fork-length	594	614	935	1145	1230	1505
Height D^2	65	79	151	215	321	514
Height anal	68	77	154	218	236	594
Length pectoral	171	190	266	318	315	371
Head	169	175	253	300	312	370
Snout—D^1	186	194	273	329	350	399
Snout—D^2	320	341	491	601	628	738
Snout—anal	358	371	531	654	695	832
Depth	153	158	245	300	327	366
Length maxilla	65	71	102	118	120	148

TABLE 1. Morphometric data for *Thunnus albacares* caught off the Cape Peninsula.

the swim bladder. Body shape, when compared with *T. obesus*, less deep. Reaches about 400 lb in weight. Colour royal blue on back, white or silver on belly, separated by a lateral golden stripe some 5 cm wide in a fish of 1 metre. Dorsal lobe dark at its base, golden yellow above this, with a white tip in large specimens. Anal lobe similar to dorsal, but with a silver-white base. Dorsal and anal finlets bright orange yellow, with or without a thin black border.

This species has an extensive synonymy, due in large measure to the marked allometric growth of the dorsal and anal lobes. This aspect has been discussed fully by Cunningham (1910), Kishinouye (1923), Beebe & Tee-Van (1936), Schaefer & Walford (1950), Schaefer (1952), and particularly by Royce (1961, 1965).

Following Collette (1961), Collette & Gibbs (1963*a*), Royce (1961, 1965) we recognize one world-wide species of yellowfin tuna.

A consideration of the taxonomic status of the bluefin tunas

We have decided not to consider the southern Indo-Pacific and Atlantic bluefin tuna as subspecies of *Thunnus thynnus*, as suggested by Collette & Gibbs (1963*a*), and previously by ourselves (Talbot, 1964; Talbot & Penrith, 1963*a*). We have done this after a careful consideration of the position in South African waters, where these two forms overlap in distribution.

There are clearly at least three series of populations, one series being found in the Atlantic and Mediterranean, another in the northern Indian and Pacific oceans and a third in the southern Atlantic and Indo-Pacific. They can be distinguished from each other in almost all individuals on a number of characters, including gill-raker counts, skeletal differences, and coloration.

The large bluefins found in summer at the Cape have the typical characteristics of the populations known from the Atlantic Ocean, the clearest being a high gill-raker count. The large populations of smaller bluefin found in the area in winter have the characteristics of southern Indo-Pacific fishes (low gill-raker counts and bright yellow peduncle keels). It is therefore likely that these fishes belong to the North Atlantic and southern Indo-Pacific groups of populations respectively and return to them. Until these fish are actually marked and recovered this must remain an assumption.

Given this assumption there is a reasonable case for separating the bluefins at the Cape into two species. Gill-raker counts, coloration, and skeletal differences are clearly marked between the summer and winter populations. No merging of differences or different combinations of characters are found, although the two forms are sympatric at one time of year. Two isolating mechanisms seem to have developed. There is a difference in breeding times, with the southern fishes feeding at the Cape in the southern winter, with completely inactive gonads, so apparently breeding in the southern summer, and with the northern fishes present in the Cape in the southern summer with again completely inactive gonads, and apparently breeding elsewhere in the southern winter. These characteristics indicate that different behavioural characteristics

have developed which keep them genetically apart in spite of their sympatry during some part of the year at the Cape. We consider that there is sufficient genetic isolation, causing visible morphological differences, to justify accepting the two bluefins found at the Cape as separate species, although the division of the bluefins is clearly of more recent date than that of the other species.

The earliest name available for a southern ocean species is *Thunnus maccoyii* (Castelnau, 1877).

The position of the third bluefin, the northern Indo-Pacific species, at times referred to as *T. orientalis*, is beyond the scope of this paper. Nakamura (1965) appears to consider it to be no more than a subspecies of *T. thynnus*, a position retained in the authoritative work of Gibbs & Collette (1967).

Thunnus thynnus (Linnaeus)
Atlantic Bluefin Tuna

Scomber thynnus Linnaeus, 1758: 297.
Thunnus thynnus: Barnard, 1927:798. Molteno, 1948:16. Smith, 1949:298. Talbot & Penrith, 1962:558, 1963*a*:637.

Entire ventral surface of liver covered with blood-vessels forming dense striations. Pectoral relatively short, not reaching past the eleventh or twelfth dorsal spine. Length of dorsal and anal lobes short. Gill-rakers (South African specimens) 12 – 15 + 26 – 31, total 37 – 44 (see table 2). (Morphometric data given in table 3.)

Gill-rakers	31	32	33	34	35	36	37	38	39	40	41	42	43	44
T. maccoyii	1	2	3	5	1	1								
T. thynnus											1		1	1

TABLE 2 (South African specimens only)

Colour of body dark blue-black above, with white below, in life or freshly dead said to be separated by a yellow or iridescent blue band (Migdalski, 1958; Tiews, 1963). Pectoral fin dark silver at base, dark grey or black distally with red patches. Dorsal lobe dark, with yellow and red near tip. Anal lobe silver with red and yellow as dorsal lobe. Finlets yellow with broad black edging. Caudal fin dark with red or yellow posterior edge. Peduncle keels dark. Reaches 1,600 lb (Crane, 1936), and reputedly 2,000 lb. South African specimens were all adult.

	Thunnus thynnus				
Fork-length	2151	2671	Snout—D^1	585	740
Height D^2	362	422	Snout—D^2	1075	1345
Height anal	353	366	Snout—anal	1220	1537
Length pectoral	402	400	Depth	522	695
Head	558	675	Length maxilla	220	258

TABLE 3. Morphometric data for *Thunnus thynnus* caught off the Cape Peninsula.

The distribution and taxonomy of Atlantic bluefins have been the subject of much controversy. Storer (1867) differentiated western Atlantic fishes from those on the European side under the name *T. secundodorsalis*. The validity of *secundodorsalis* was questioned by Jordan & Everman (1926) and Godsil & Holmberg (1950), but they did not formally suppress the name. Ginsburg (1953), however, claimed the two populations were distinct on morphometric and meristic grounds. His meristic characters show slight differences in means, but it is not certain whether these would disappear with larger samples.

Rivas (1954) considered there to be one Atlantic species, with two separate breeding populations racially or subspecifically distinct. Sella's (1927, 1929) suggestions that an exchange of fish took place across the Atlantic has now been thoroughly proved by Mather's tagging studies (1960, 1962, 1963). Tagging returns indicate that *T. thynnus* can cross from America to Europe, and is, therefore, quite capable of swimming to the Cape.

Thunnus maccoyii (Castelnau)
Southern Bluefin Tuna

Thynnus maccoyii Castelnau, 1872:109.
Thunnus maccoyii: Nakamura, 1965:18. Penrith, 1967:535
Thunnus thynnus (*non* Linnaeus) Talbot & Penrith, 1962:558.
Thunnus thynnus maccoyii: Serventy, 1956*a*:13.
Thunnus thynnus orientalis non Temminck & Schlegel, 1844:94. Talbot & Penrith, 1963*a*:630. Talbot, 1964:201. De Jager, 1963:589. De Jager *et al.*, 1963:11.

Liver completely striated ventrally. Pectoral short, scarcely reaching the origin of the second dorsal. Dorsal and anal lobes short. (Table 4 gives morpho-

	Thunnus maccoyii			
Fork-length	1045	1202	1235	1351
Head	30·4	30·2	29·2	29·1
Snout—D^1	31·5	31·7	33·1	30·4
Snout—D^2	55·3	54·7	55·7	53·9
Snout anal	60·2	60·3	63·4	58·7
Depth	26.7	26·5	26·2	26·9
Length pectoral	23·1	20·4	23·6	21·6
Height D^2	12·9	12·6	14·1	11·6
Height anal	13·3	13·0	13·6	11·6
Length maxilla	12·2	12·2	12·1	11·3
Gill-rakers	33	34	33	34

TABLE 4. Morphometric data for *Thunnus maccoyii* caught off the Cape Peninsula.

metric data.) Gill-rakers 30–38 in total, but usually 33–34 (see table 2). Swim bladder variable, usually being better developed in large fishes. Colouring in general similar to *T. thynnus*, but no trace of yellow on the dorsal and anal lobes and the pelvic in fishes examined by us. The peduncle keels are usually bright yellow, sometimes darker, but always with a translucent, almost hyaline, look, unlike the solid black of *T. thynnus*. Finlets yellow with a thin black edge.

Thunnus alalunga (Bonnaterre)
Longfin, Albacore

Scomber alalunga Bonnaterre, 1788:139 (based on a description by Cetti, 1777).
Thynnus alalonga: Günther, 1860:366. Gilchrist, 1902:128. Thompson, 1918:108.
Germo alalunga: Smith, 1949:299. Molteno, 1948:29.
Germo alalonga: Barnard, 1927:799.
Thunnus alalunga: Talbot & Penrith, 1960:1, 1962:558, 1963*a*:609. Talbot, 1964:199. De Jager, 1963:589. De Jager *et al.*, 1963:11.

Ventral surface of liver densely covered with striations. Pectoral fins sabre-shaped and elongate, reaching to or beyond the first anal finlet. Dorsal and anal lobes low. Gill-rakers 8–9 upper, 19–21 lower, 28–30 total. Back dark metallic blue, belly silver-white, separated by an iridescent blue band, which disappears after the fish is gaffed. Pectoral fin black, ventral and dorsal lobes dusky. First dorsal lobe colourless, anal lobe silver. Posterior edge of caudal fin white, dorsal finlets pale yellow with dusky edges, ventral finlets dark. Reaches 80 lb, usually smaller. Flesh paler than other species. (See table 5.)

	Thunnus alalunga				
Fork-length	818	864	892	975	993
Height dorsal[2]	93	111	118	128	128
Height anal	94	107	122	134	130
Length pectoral	352	387	409	397	408
Head	233	254	273	290	289
Snout—dorsal[1]	271	287	320	232	321
Snout—dorsal[2]	482	502	574	573	583
Snout—anal	514	535	610	631	631
Depth	203	220	257	277	255
Length maxilla	90	97	104	112	105
Gill-rakers:					
upper	20	21	21	21	20
lower	10	9	9	9	10
Total	30	30	30	30	30

TABLE 5. Morphometric data for *Thunnus alalunga* caught off the Cape Peninsula.

This is considered to be one widely ranging species and while little is known of its movements in the Indian or Atlantic oceans, it has been shown to make trans-Pacific migrations (Blunt, 1954; Otsu, 1960; Uchida & Otsu, 1961; Clemens, 1961, 1963).

Thunnus obesus (Lowe)
Bigeye

Thynnus obesus Lowe, 1839:78.
Thunnus obesus: Talbot & Penrith, 1960:1, 1961*a*:1, 1961*b*:240, 1962:558, 1963*a*:624. Talbot, 1964:203. De Jager, 1963:589. De Jager *et al.*, 1963:11.

Liver showing patches of peripheral striations. Pectoral fin one quarter to one sixth of total length, reaching the end of the dorsal lobes, becoming relatively shorter with increased size. Dorsal and anal lobes short compared with *T. alba-*

Thunnus obesus

Fork-length	1172	1356	1483	1582	1784
Height D^2	170	223	220	285	301
Height anal	175	214	213	271	290
Length pectoral	319	356	369	410	422
Head	337	391	395	446	493
Snout—D^1	362	401	447	469	518
Snout—D^2	652	747	828	836	946
Snout—anal	652	853	924	937	1057
Depth	325	367	392	415	468
Length maxilla	141	152	172	182	199

TABLE 6. Morphometric data for *Thunnus obesus* caught off the Cape Peninsula.

cares. Gill-rakers 7–9 upper, 18–20 lower, 26–28 total. (See table 6 for morphometric data.) Swim bladder with very deep paired pits anteriorly, and no central thick connective tissue ridge pressing down into the swim bladder as in *T. albacares*. In spite of the name the eye of the bigeye tuna is not much larger than in the other tunas. The eye of *T. alalunga* is actually greatest in relation to fork-length (5·3–5·7). The eyes of both *T. albacares* (3·2–6·2%) and *T. maccoyii* (3·1–4·1%) may occasionally reach the size range of *T. obesus* (3·5–4·6%) at the same size. (See also Mather, 1963.)

Key to the genus Thunnus

The following key has been constructed to include all species which may be found to comprise the genus *Thunnus*:

1 (*a*) Pectoral fin reaching beyond posterior margin of anal fin 2
(*b*) Pectoral fin not reaching beyond posterior margin of anal fin, although it may reach anal fin insertion 3
2 (*a*) Posterior edge of caudal fin with a distinct white edging; ventral surface of liver dark and densely striated .. .. *T. alalunga*
(*b*) No white edging on posterior edge of caudal fin; liver pale and at most only slightly striated (juvenile tuna) 3
3 (*a*) Liver without striations ventrally 4
(*b*) Liver with distinct striations ventrally 6
4 (*a*) Total gill-raker count over 25 (usually 27–31); all fins bright yellow including the first dorsal .. .. *T. albacares*
(*b*) Total gill-raker count less than 25 5
5 (*a*) Body deep (depth over 27% of fork-length); distance snout to anal fin more than 56% of fork-length. Small air bladder present .. .. *T. atlanticus**
(*b*) Body slender (depth under 26% of fork-length); distance snout to anal fin less than 60% of fork-length. No air bladder .. .. *T. tonggol**
6 (*a*) Total gill-rakers more than 38; often over 400 lb weight .. .. *T. thynnus*
(*b*) Total gill-rakers 36 or less; usually less than 500 lb 7
7 (*a*) Ventral striations on liver in groups near margin. Peduncle keel dark, pelvic fin with red and yellow markings .. .. *T. obesus*
(*b*) Ventral surface of liver fully striated 8
8 (*a*) Peduncle keels bright yellow or hyaline; no yellow markings on pelvic fin. Deep lateral pocket in pectoral region of roof of body cavity .. .. *T. maccoyii*
(*b*) Peduncle keels opaque black, yellow markings on pelvic fins. Shallow lateral depression in pectoral region of roof of body cavity .. .. .. *T. orientalis**

* Not known from South African waters.

Distribution and Migrations

Hydrography

Before the detailed distribution of tunas in the areas surveyed can be discussed, some knowledge of the physical environment is required. The coastline of southern Africa is shown in figure 1, together with the positions of the stations fished. The distribution of water masses in the region of the Cape of Good Hope is complex and variable, although the broad pattern of the currents is known (fig. 3).

Offshore the coasts are ringed by subtropical water; inside this subtropical water, the waters of the east and south coasts are warm and saline, whereas the waters bounding the west coast are cold and of low salinity, although rich in nutrients.

The major water masses in the South African region which were fished during this survey are:

(*a*) South Atlantic Subtropical Surface Water

This water mass is part of the South Atlantic anti-cyclonic gyral. To the south it is bordered by the West Wind Drift, from which it is separated by the Subtropical Convergence at about 37°–40°S. Eastwards it is bordered by the Agulhas Current south of the African continent and the surface waters of the Indian ocean, but there is often no sharp boundary between these waters, and the South Atlantic Subtropical Surface Water may move as far east as Cape Agulhas or further when the force of the Agulhas Current is weak. The temperature and salinity decrease southwards; at 20°S they are of the order of 23°C; 36°/$_{oo}$, while at 34°–35°S they have dropped to 15°–21°C; 35·4–35·9°/$_{oo}$ (Clowes, 1950).

(*b*) Benguela Current

The Benguela Current has recently been discussed in great detail by Hart & Currie (1960), who have shown that the current is caused by local southerly winds inducing an offshore movement of surface water in a north-westerly direction, which in turn causes upwelling. This upwelled water is separated from the north and west-flowing waters of the South Atlantic gyral by a convection cell. It was formerly thought (Clowes, 1950) that the upwelled water had its origin in the Antarctic Intermediate Water, but Hart & Currie have shown that the upwelled water has its origin at 200–300 metres, far above the depth of the Intermediate Current, and originates from Atlantic Central Water. The water inshore of the convection cell is cold (9°–15°C), the temperature depending largely on the degree of upwelling, and of relatively low salinity (34·5–35·1°/$_{oo}$), although rich in phosphates, silicates, and nitrates. It is quite common during calm weather in summer for the surface waters to warm up and a marked thermocline to exist. At station 3425 in February 1958 *Africana II*, a research vessel belonging to the Division of Sea Fisheries, found surface water of 17·55°C and salinity 34·97°/$_{oo}$, while at 30 metres, although the salinity remained con-

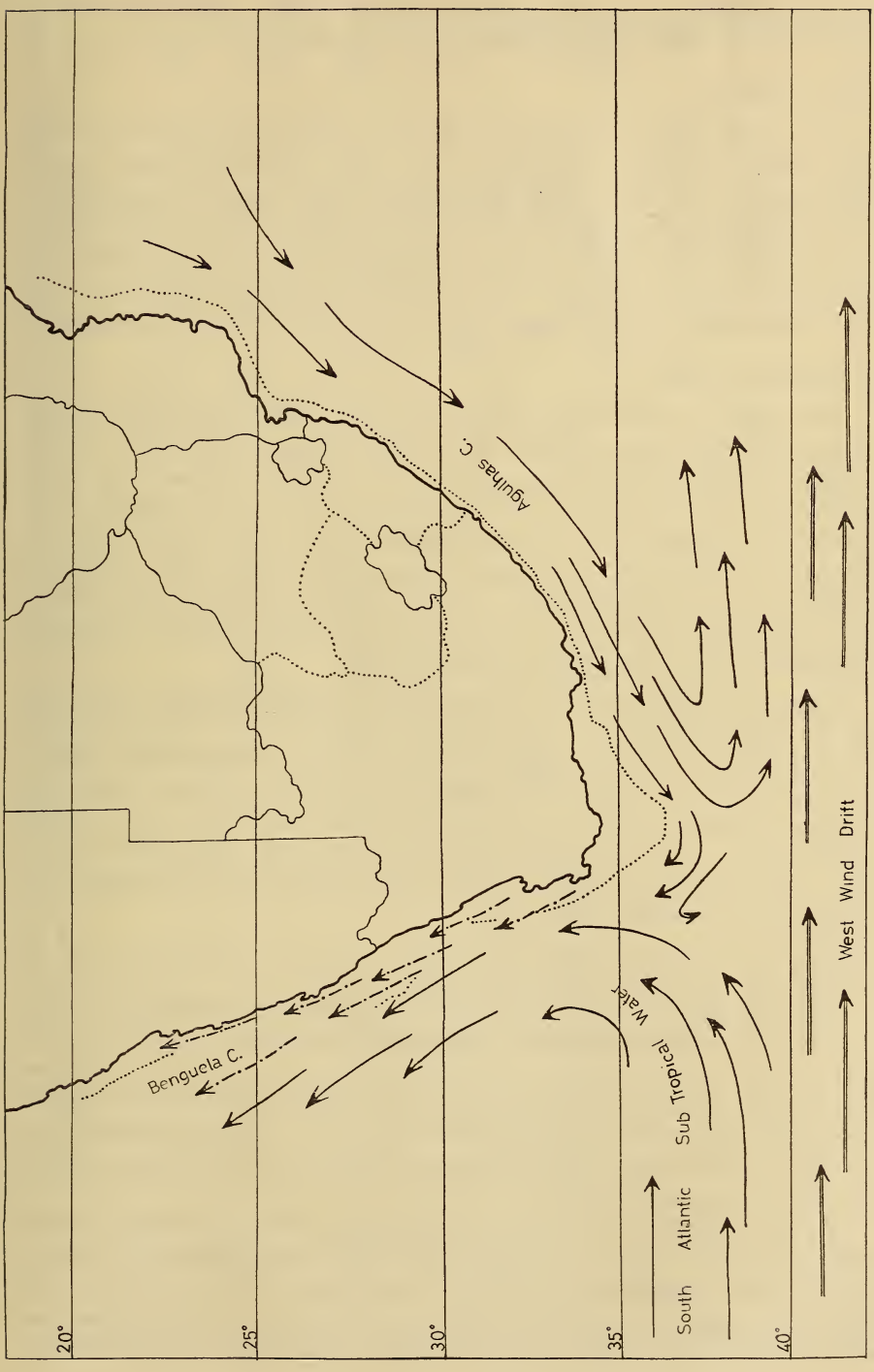


Fig. 3. Current systems around South Africa under typical summer conditions.

stant, the temperature had dropped to 12·14°C. Other stations in the area showed the same effect (Div. Sea Fish. Ann. Rep. 1960).

(*c*) Central Water

The origin of this water is believed to be the sinking of surface water at the Subtropical Convergence (Sverdrup *et al.* (1942) although Clowes (1950) suggests that it is the direct result of mixing between surface subtropical water and the underlying Intermediate Water. In the present survey only Atlantic Central Water which contributes to the Benguela Current is involved. The temperature range is 5°–12°C, and the salinity 34·3–35·1‰ (Sverdrup *et al.*, 1942). It lies below the surface waters at 150–500 metres (Hart & Currie, 1960).

(*d*) Agulhas Current

The Agulhas Current forms part of the South Indian ocean gyral, being derived from the southern branch of the South Equatorial Current, flowing down the west side of Madagascar, and down the southern African coast to the tip of Africa. The currents in the Mozambique Channel are thought to be variable, but may contribute at certain times of year to the Agulhas Current. The speed of the current is considered to be 3–4 knots (*African Pilot*). When the current reaches the Agulhas Bank, it swings away from the South African coast, following the edge of the bank, moving in a south-westerly direction, and then turning eastwards as the Agulhas Return Current.

There is indication that a varying amount of Agulhas Current water may cross the Agulhas Bank, or round its tip, to mingle with the South Atlantic Subtropical Water in the area of the survey, its temperatures generally being in the region of 20°–24°C and the salinity 35·4–35·6‰, although both may decrease near the coast, but are not known to fall below 17°C; 35·3‰. The inshore water between the Agulhas Current and the coast, where the current is often northward flowing (Gilchrist, 1903), was not fished, as the water depth was not sufficient for the type of gear used.

(*e*) South Indian Ocean Subtropical Water

This water mass is analogous with the South Atlantic Subtropical Water and, although in general slightly less saline, is several degrees warmer. *Discovery II* found a temperature of 26·58°C and salinity of 35·31‰ at 21° 44′ E south of the Cape in April (Clowes, 1950). In the south-west Indian ocean, temperatures during this survey ranged from 18·7°–23·2°C in August 1962 and from 22·7°–26·7° in February 1963. This water is separated from the South African coast by the Agulhas Current.

Clowes (1950) has discussed the hydrography of South African seas in detail, and much of the above is based on his work, except that upwelled water off the coast is considered to be Central Water (after Hart & Currie, 1960) rather than Antarctic Intermediate Water. Clowes also gave T/S curves for each 5° of longitude from 5°W to 45°E within latitudes 30°–35°S. The curves

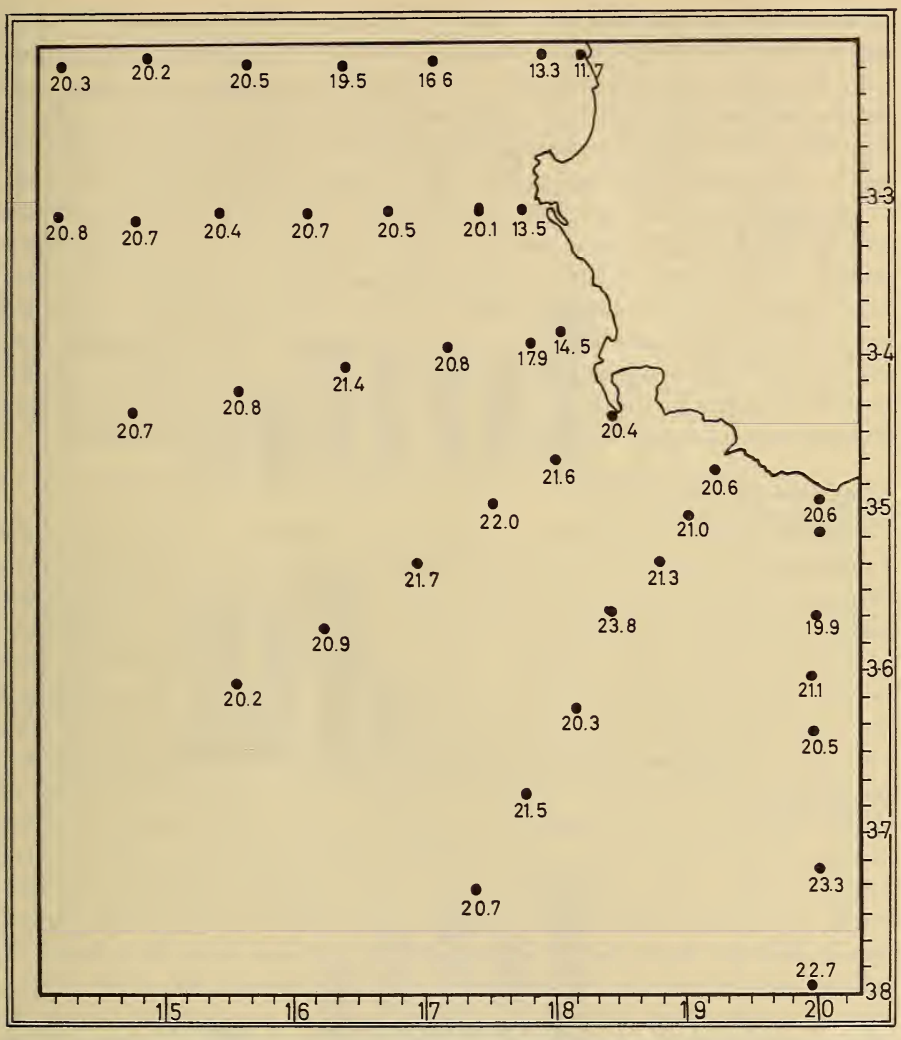


Fig. 4. Temperatures of the surface water off the western Cape in March. Taken from data in the Annual Report Division of Sea Fisheries, 1957–1958.

for the region 5°W to 15°E show clear differences from those for the region 25°–45°E, although crossing several times. Clowes considers the water west of 15°E to be purely Atlantic and that east of 25°E to be purely Indian. In the area 15°–25°E, however, there is a great deal of mixing, both between Atlantic and Indian surface water, and between surface water and upwelled Central Water.

In winter the Agulhas Current is weakened and due to the prevailing winds off the Cape at this time being westerly, the Atlantic water may penetrate eastwards, often to or even beyond Cape Agulhas, and deflect the Agulhas Current south and east (Buys, 1959; De Jager *et al.*, 1963). In summer, however,

the conditions are reversed; the Agulhas Current is flowing strongly, the prevailing winds are southerly and easterly and tend to blow the surface water away from the coastline along the west coast. This results in upwelling, and inshore the South Atlantic Surface Water becomes mixed with Central Water. A portion of the Agulhas water appears to continue into the Atlantic (Dietrich, 1935), and there is often in summer a broad band of very warm water (over 20°C) right round the Cape from the Atlantic to the Indian ocean outside the cold upwelled water. Figure 4 shows surface temperatures and salinities prevailing off the Cape in March 1958 (drawn from data in Div. Sea Fish. Ann. Rep. 1960). It clearly shows in this case that, while there is cold upwelled water close inshore from Cape Point westwards, there is very warm water outside, while salinities suggest that Agulhas water is only reaching Danger Point; between it and Cape Columbine there is an area of lower salinities, suggestive of mixed water between the Agulhas water and the Atlantic surface water.

Temperature Tolerance of Tuna

Much work in the field of temperature tolerance of tuna, especially *T. alalunga*, has been done off the Californian coast. As long ago as 1917 Thompson (1917, 1919) suggested that small changes in water temperature might cause marked changes in the distribution of oceanic fishes, as did Hubbs & Schultz (1929) and Walford (1931). Statistics of the Californian tuna industry show great fluctuations in catch; after several good years there are one or two bad ones. In 1925 the catch of tuna was 25 million lb, and in 1926 it dropped to 3 million lb, for instance. Hubbs (1948) was the first to investigate the problem, and concluded that *T. alalunga* had a temperature range of 15·5°–18·4°C, and that when this temperature range did not occur in the fishing area during the tuna season, the fishery did not develop. Later workers (Clemens, 1957, 1958, 1961; Craig, 1959, 1960; Powell & Hildebrand, 1950; Powell *et al.*, 1952; Neave & Hanovan, 1960; Radovich, 1960, 1961) found slightly different limits, but all agreed that the absolute limits for a fishery to develop were above 14·4°C and below 20°C. Occasional fish could still be taken at temperatures above 20°C, but only one fish was recorded below the minimum (Schaefers, 1953). Clemens (1958), Craig (1959, 1960), and Radovich (1960, 1961) found that small fluctuations in surface temperature were of great importance, since a slight rise above the normal, which would result in a northward movement of the isotherms beyond their normal latitude during the tuna season, would cause the fish to move north of their usual area. They found that the best fishing area for the season could be accurately determined by means of a pre-season temperature survey of the usual area, and so successful has this forecasting proved in the last few years that Johnson (1960) could state: 'The value of the sea temperature as a forecasting tool of albacore (*T. alalunga*) distribution has been amply demonstrated during the last four years.' In the Californian area similar temperature effects were found for all other tuna species. Uda (1961*a*, *b*) has made similar observations for the western Pacific ocean.

The temperatures quoted in literature are almost invariably surface, and not ambient temperatures, because of the difficulty of obtaining the latter. Even with fishes caught on long-lines whose depth is more or less known, catches may be made while hooks are sinking or rising. Squire (1963) gives both surface temperatures and those at the hook depth. Surface temperatures are used here,

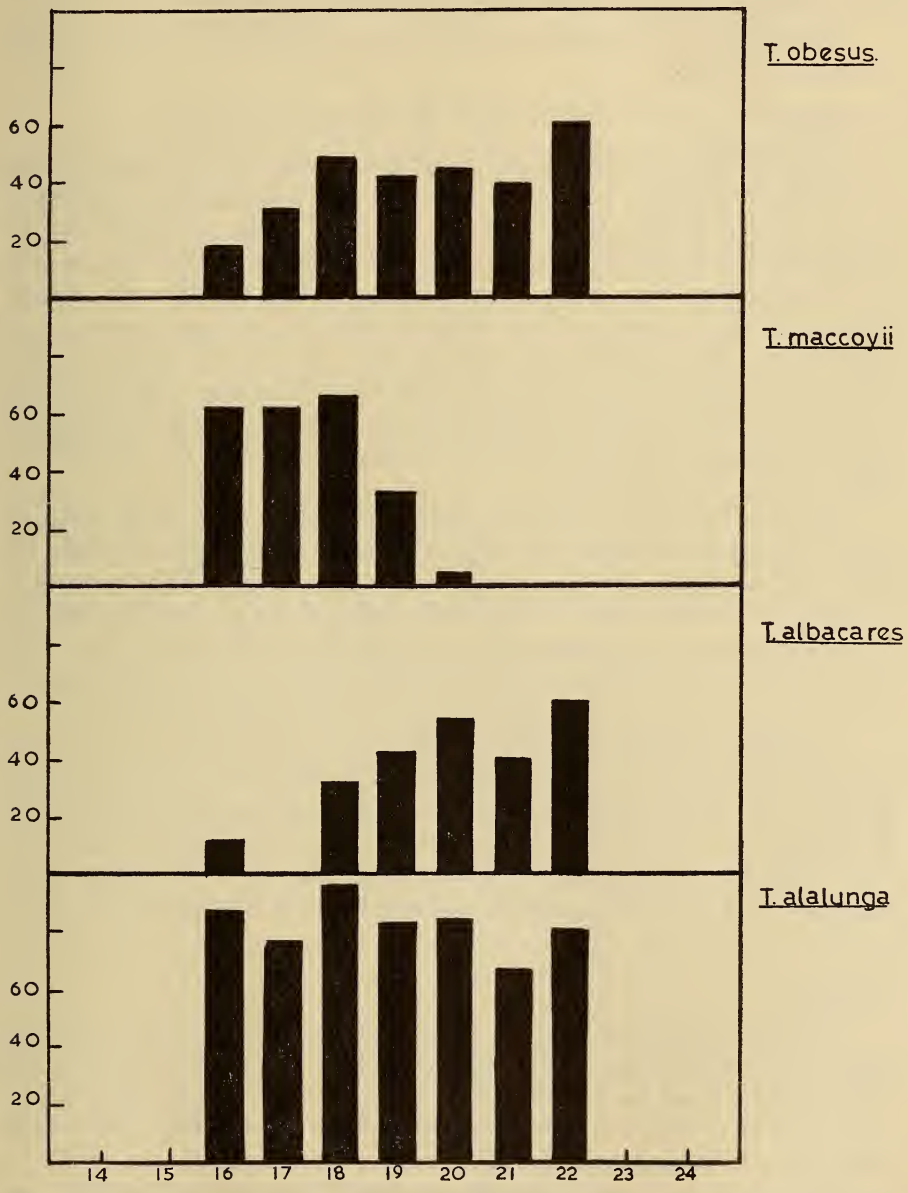


Fig. 5. Percentage of successful stations for each species at various water temperatures (to the nearest 1·0°C). Only temperatures at which more than five stations were occupied are given.

but in appendix A subsurface temperatures are given for all stations where known.

There seems to be a range of temperatures within which a species of tuna is usually found in any one area, but occasionally it may also be found outside this range. We are calling the normal range the 'optimum range', merely on the basis of the fact that the fishes are usually found within it.

The correlation between catch and surface temperature is shown in the histogram in figure 5.

T. alalunga

As shown above, *T. alalunga* off the Californian coast has a normal temperature range of 14·4°–20°C. In other areas, however, slightly different temperatures may be preferred. Alverson (1961) found off British Columbia that the population of north Pacific *T. alalunga* with which he was dealing had an optimum temperature range of 13·3°–16·1°C (54°–61°F). In equatorial regions, on the other hand, there are tuna fisheries taking *T. alalunga* in water of up to 21°C according to Rosa & Laevastu (1961) and Laevastu & Rosa (1963) as shown by their histogram although their chart of fishing areas shows fishing up to the Equator in surface temperatures over 25°C. According to Kishinouye (1923) *T. alalunga* is found in the region of Japan in water of 13°–24°C. Squire finds a range of 11·5°–28·2°C.

Attempts have been made to find the optimum surface temperature (as defined above) for *T. alalunga* (as well as the other species present) during the survey off the Cape. Unfortunately to do this requires a large number of samplings at a wide range of temperatures, which the 111 stations occupied during the present survey did not have. Observations in the centre of the range were adequate, but this was not the case at the possible extremes. The correlation between catch and temperature is shown in the histogram in figure 5.

T. alalunga was taken almost throughout the range of temperatures. Only at temperatures above 22°C was this species never taken. The only stations fished at temperatures higher than 22°C were off the east coast, however, where *T. alalunga* was never found, perhaps for other reasons. On the basis of our observations at the 91 stations at which this species was taken, *T. alalunga* has an optimum range of 16°–22°C, and is occasionally taken in temperatures as low as 14°C.

T. maccoyii

Relatively little work has been done concerning the temperature requirements of *T. maccoyii*. None of the authors who have studied the populations off the Australian coast have published temperature observations of this species, except Robins (1963), who mentioned that adults are seldom found at temperatures above 21°C, and 'juveniles' do not occur above 19°C.

By referring to figure 5 it may be seen that *T. maccoyii* is only rarely taken at temperatures above 19°C in the Cape area, the drop-off in catch rate above

this temperature being very marked. The lower limit of *T. maccoyii* is unfortunately not clear; below 15·5°C it seems to become less common.

T. thynnus

According to Mather (1963) and Tiews (1963) *T. thynnus* has a wide temperature range of 12–25°C. In False Bay, Cape Town, this species is only found in water above 20°C.

T. albacares

More observations on the temperature requirements of this species have been made than for most other species, except perhaps *T. alalunga*. Kishinouye (1923) gave a total range for this species of 14°–27°C, but gave as an optimum temperature range 22°–24°C.

In the Pacific ocean, Kamimura & Honma (1963) have shown that the best catches of *T. albacares* are made in the equatorial area between 5°N and 10°S, with the centre of distribution just south of the Equator, where the temperature range is 22°–26°C. Schaefer *et al.* (1963) agree that this species is usually found in water above 20°C, but add that they may occasionally be found in water below 20°C. *T. albacares* in the north-east Pacific is, like *T. alalunga*, affected by small changes in the surface temperature of its normal area, moving polewards during periods of warm water both off California and South America (Blackburn, 1960; Schaefer, 1961), and suggesting that *T. albacares* may avoid water which has a temperature of over 25°C.

Squire (1963) found that in the north-west Atlantic the yellowfin could be found in water ranging from 18·4° to 28·8°C, with an average temperature at which fish were caught of 25·2°C.

Tsuruta (1961) found *T. albacares* in the south-west Indian ocean in water with a range of temperature of 19·0°–25·3°C.

Off the Cape (fig. 5), the histograms suggest that the sampling was conducted at the lower end of the temperature range, since in all figures, both of percentage catch rate and successful stations, the catch seems to be increasing with increase in temperature. Little fishing was done in warmer water, however. It is worth noting, too, that *T. albacares* has a wide range of temperature tolerance, since off the Cape it was the only species to occur over the whole range of temperatures fished (13·8°–24°C); there was, however, no sign of an optimum temperature. There is some indication that the optimum temperature range of *T. albacares* is higher in this area than that of the other species, an observation that is in agreement with the findings of Squire (1963) for the north-west Atlantic, and the tentative conclusions reached by De Jager (1963) and De Jager *et al.* (1963) for the Cape. Figure 5 suggests that *T. albacares* is normally found only in water above 17·5°C.

T. obesus

While *T. obesus* is in general a species of low latitudes, being found in its greatest quantities just north of the Equator (Kamimura & Honma, 1963), it

does have a very wide range of temperature tolerance. In the Japanese area Kishinouye (1923) recorded that the temperature range was 13°–25°C with an optimum of 22°–24°C. Tsuruta (1961), in the south-west Indian ocean, found this species in water ranging in temperature between 17°C and 25°C. Other wide ranges of temperature recorded are 12·2°–28·8°C (54°–84°F) in the eastern Pacific (Alverson & Peterson, 1963) and 13·5°–27·3°C in the north-west Atlantic (Squire, 1963).

During the survey very few *T. obesus* were taken, too few to give a true picture of their temperature range in this area; also, like *T. albacares*, there were too few stations occupied in warm water, above 21·5°C.

In conclusion, it can be said that, although the tuna found off the Cape have a wide range of temperature tolerance, they are usually found within a restricted range of temperature, which in *T. maccoyii* is low (below 19°C) and in *T. obesus* and *T. albacares* higher (above 17·5°C). *T. alalunga*, however, seems to have a wide optimum temperature range.

Changes in the tuna population

Prior to 1960 the opinion was widely held that tuna were found off the Cape during the summer months only (Horne, 1959), although whaling skippers working off Cape Columbine in the winter of 1957 reported seeing tuna. During the summer months (November to April) the sport fishing vessels took large numbers of *T. albacares* and a small number of *T. alalunga* (Horne, 1959). In some years small numbers of what were probably large *T. thynnus* were also taken by beach seines at this time, as well as smaller specimens by anglers off the rocks at Rooikrantz, near Cape Point (*Cape Times*, 31/12/1945, 5/1/1946, and South African Museum records). In addition, two specimens of *T. obesus* were caught in November 1959 by trolling off Slangkop, Cape Peninsula (Talbot & Penrith, 1961*b*).

It was therefore confidently expected that during the winter months long-lining would produce few or no tuna, and doubts were expressed as to the desirability of continuing the survey during the winter. It was thus extremely surprising to find that during the winter period the catches, far from showing any tendency to diminish, actually increased, though changing in species composition. The change is shown diagramatically in figure 6. Referring to figure 6 it may be seen that *T. alalunga* is the only species present off the south-western Cape at all times of the year. During the months October to May, what may be termed the summer population of tunas is present off the Cape. This is composed of *T. albacares*, *T. obesus*, *T. alalunga* (in the main comprising small fish of less than 950 mm fork-length of this species), and a small number of *T. thynnus*. During May to November a different population of tunas is present, being composed of *T. maccoyii* and *T. alalunga*, but the latter species is more abundant than during the summer due to the addition of large numbers of larger individuals of over 950 mm fork-length. During the winter occasional specimens of *T. albacares* and *T. obesus* are found, but in such small numbers that they may be

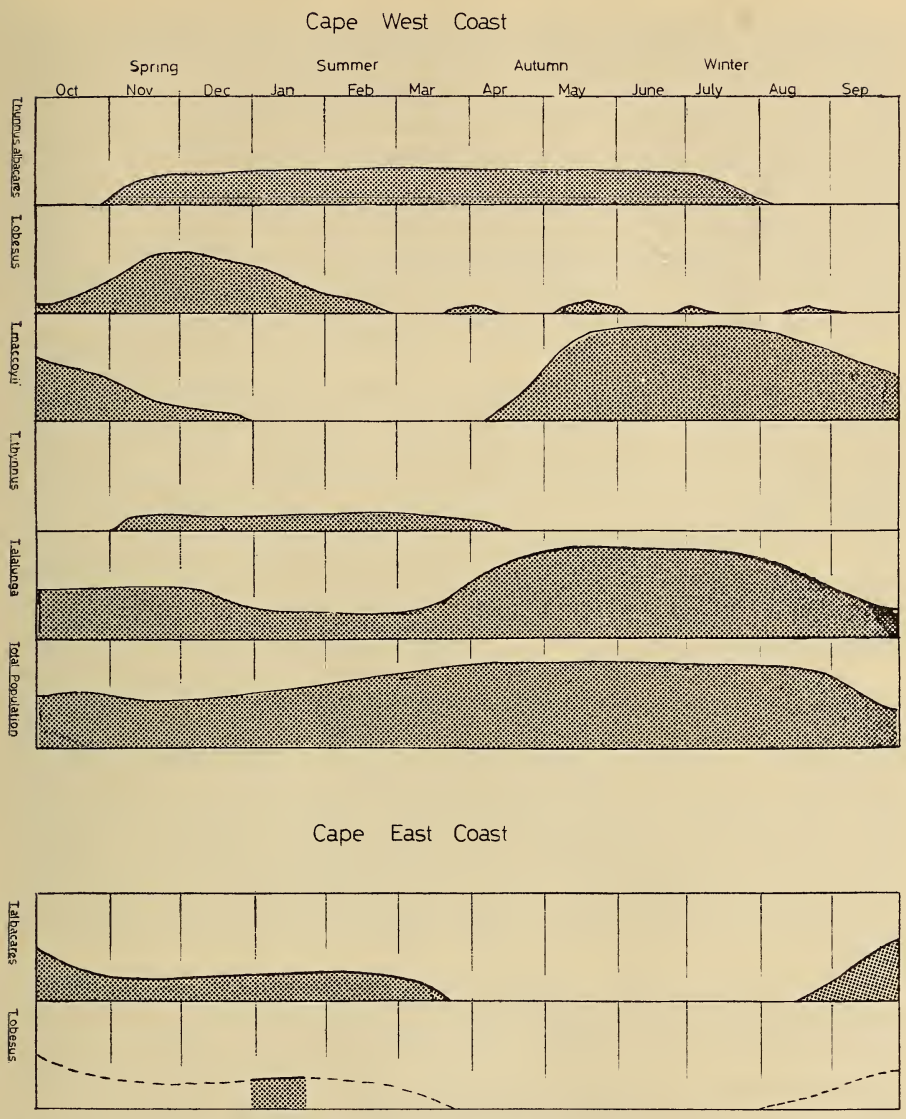


Fig. 6. Annual changes in tuna populations in the waters west of Cape Town and on the South African south-east coast. Only *Thunnus albacares* and *T. obesus* were taken in the latter area. Height of shaded area is proportional to the catch per hundred hooks of long-line gear, as shown by our survey.

presumed to have been individuals which did not migrate from the Cape with the main population.

Off the east coast, in the area surveyed, between Cape Agulhas and Cape Recife, there was a marked difference both in the species composition and in the numbers of tuna present in comparison with the western Cape. No *T. alalunga*,

T. thynnus or *T. maccoyii* were found, nor have they ever been definitely recorded from this area. Only two species, *T. obesus* and *T. albacares* are definitely found in this area. During summer *T. obesus* and presumably *T. albacares* were present, but owing to bad weather only two stations could be fished in this area in summer; at these stations four *T. obesus* were taken. In late summer both species were found in small quantities, while in winter, although stations were occupied in warm water, no tuna of any sort were caught. At the end of April 1960 large quantities of *T. albacares* and a smaller number of *T. obesus* were caught between Cape St. Francis and Cape Recife in water of 18°–20·3°C, although off Cape Infanta, in water of similar temperature (18·3°C) no tuna were found.

In the south-west Indian Ocean so few fish were caught during the two cruises on the S.A.S. *Natal* that no clear results could be obtained. Noteworthy was the finding of *T. alalunga* close inshore east of Durban, from where it had been recorded only once previously (Molteno, 1948). It was also found that there seemed to be a marked difference in the number of tuna present in summer (February 1963) and in winter (August 1962). During winter tunas were found in fairly small quantities on the stations east of Durban, *T. alalunga* and *T. albacares* being the species present. During the summer tunas were almost completely absent in the area surveyed, only two *T. albacares* and one *T. obesus* being found. As in the area further south, no *T. thynnus* were obtained.

To our knowledge the first survey of the area south of Madagascar and east of Durban was done in January 1961, by the R.V. *Koyo-Maru* belonging to the Shimonoseki College of Fisheries, Japan. She obtained catch rates of 2·0% for *T. albacares*, 1·1% for *T. alalunga*, and 0·2% for *T. obesus* (Tsuruta, 1961), a total catch rate far in excess of the total catch rate for the February *Natal* cruise of 0·3%. A possible reason for this seeming anomaly is patchy distribution. Tsuruta's data suggest small shoals very widely separated, and since the *Koyo-Maru* used a far longer length of long-line than the *Natal*, thus sampling a far greater area of the sea, this may partly account for the apparent difference in results.

This area has, however, become a commercial fishing area since the survey of the *Koyo-Maru*, and, judging by the aerial sightings of vessels off Durban (Pinkerton, pers. comm.) and by landings of frozen tuna at Durban by Japanese long-liners (Durban Customs, pers. comm.), most of the fishing in this area is done in winter. It seems therefore that the indication given by the cruises on S.A.S. *Natal*, that tuna are more plentiful in the south-west Indian ocean in winter than in summer, is correct, although based on scanty evidence at present.

The Distribution of Tuna in Relation to Hydrographic Conditions

Off the Cape there are both marked annual changes in tuna populations and great annual changes in the hydrographic conditions of the surface water masses. The tuna populations change at the same time as the water masses, suggesting a causal relationship. The main determinants of horizontal distribu-

tion in a pelagic open-ocean fish such as tuna are probably the necessity to find available food, the necessity to remain within suitable hydrographic conditions, the necessity to satisfy the particular, usually more narrowly selected, hydrographic conditions during the breeding season, and also behavioural factors such as schooling behaviour and inherent migratory urges. It would be naïve to consider the spatial position of tuna to be anything but the result of a complex inter-relationship of a number of these factors at any one time. Nevertheless, given adequate feeding at a non-breeding season, temperature (which has been considered by Yabe *et al.* (1963), to be the most important factor determining the suitability of the hydrographic environment) may be closely linked to distribution.

Food and feeding will be discussed in a later section, but it should be noted that the Cape area, owing mainly to the upwelling of the water forming the Benguela Current, is exceptionally rich in phosphates, nitrates and silicates, and is biologically one of the richest areas of the oceans (Steemann-Nielsen, 1956), supporting vast quantities of potential tuna forage organisms such as *Sardinops ocellata*, *Maurolicus muelleri* and *Loligo reynaudi*.

Tuna require a very uniform body of water within which to breed, with no sudden changes or fluctuations in temperature. The temperature, too, must be high (24°C or higher according to Yabe *et al.*, 1963). These conditions are not met with off the Cape.

If the catch rate of fish per hundred hooks is considered as a measure of abundance, which over a series of stations fished at different times is a fair assumption, the different water masses around the Cape have very different populations of tuna. In figure 7 the populations have been expressed in number caught per hundred hooks in the different water masses. The upwelled water that forms the Benguela Current changes little in temperature from summer to winter, although it is more clearly defined in summer because of the off-shore wind systems at that time of year (fig. 3). The South Atlantic Subtropical Surface Water changes considerably, however, from summer to winter in temperature. Because of this, and the fact that species of tuna move from the Cape at different times to breed the water masses have been considered separately for summer and winter.

In summer there is much mixing of the Agulhas Current water (which rounds the Cape under certain wind conditions) and the South Atlantic Subtropical Surface Water in the area west of Cape Town where the main sampling effort of the survey was concentrated (fig. 3). These surface waters have rather similar temperature and salinity characteristics, and this, plus the problem of mixed water, makes it difficult to decide in many cases in what water a station was placed. They have therefore been considered together(fig. 7) in summer, but in winter, where there is no rounding of the Cape by the Agulhas Current, and the South Atlantic Subtropical Surface Water is much colder, they can be clearly differentiated, and we have been able to consider them separately. Summer has been considered to be from December to May inclusive, as these

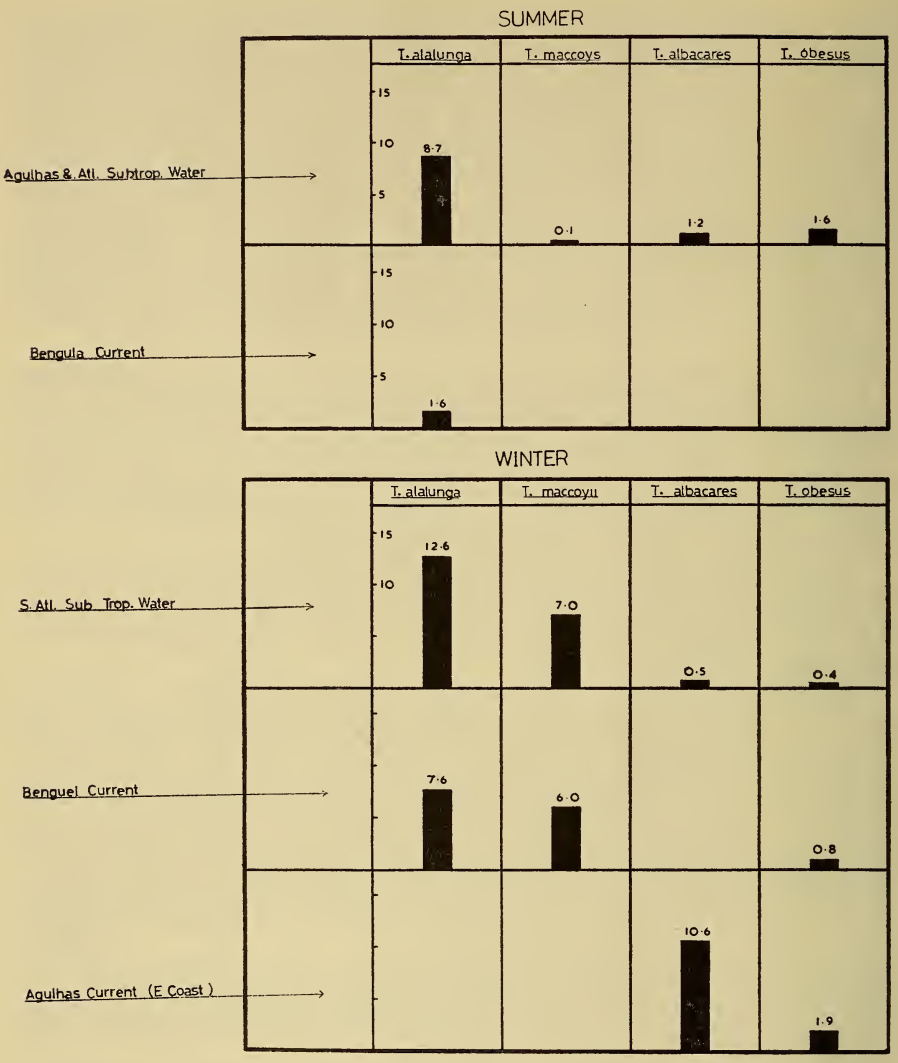


Fig. 7. Catch rate of tuna in summer and winter in the various water masses sampled. Catch rate is expressed as number of fishes taken per hundred hooks laid, and is stated above each histogram.

months showed warmer water (over 20°C) than the months June to November (below 20°C) during the eighteen months of the survey.

The Benguela Current lies inshore of the warm Agulhas Current/South Atlantic Subtropical Surface Water in summer, and is often so clearly demarcated from the latter that there is a change in surface temperature of as much as 5°C over a hundred yards, and also a change from greenish water with a high plankton concentration to clear blue warm water. Only *T. alalunga* was found

in the Benguela Current in the few stations occupied in summer. In winter, when *T. maccoyii* has reached the Cape, both this species and *T. alalunga* are found in this water mass. A few *T. obesus* were also taken in it in winter, presumably being some of the very few fish of this species that remain through the winter in the area. At 4 stations, however, all in summer, at the border of the Benguela Current, and apparently just within it, both *T. albacares* and *T. obesus* were taken in quantity. Stations further into the Benguela water at the same time gave none of these species. These stations were not included in figure 7, and are mentioned here to indicate that on rare occasions the warmer water species may move just into the borders of the Benguela, presumably to feed on the rich stocks of forage species.

In the Agulhas Current/South Atlantic Subtropical Surface Water in summer the dominant species is *T. alalunga*, and both *T. albacares* and *T. obesus* are common (fig. 7). *T. maccoyii* is absent from the Cape during summer; its presence in this water mass (fig. 7) is due to a few specimens being taken on 7 and 8 December 1960, and on 21 and 22 June 1961, i.e. just outside the limits of 'summer' as defined here. Although the two water masses are here considered together, in comparing temperature/salinity curves at the stations with those of Clowes (1950) there was an indication that *Thunnus albacares* and *T. obesus* were mostly in water of Agulhas Current origin, while *T. alalunga* was found in both waters, but mostly in South Atlantic Subtropical Surface Water. The only specimen of *T. thynnus* was taken in this water mass in December 1960. From the catches of commercial long-line boats which began operating after this survey it has become clear that at least in some summers *T. thynnus* is very much more common than this single record indicates. In the summer of 1963–4, as well as in subsequent years, a large number of this species was also taken by sports fishermen in False Bay. As they were using a technique new in the area (chumming and whole bait), it is possible that this species may have been here in other years.

In the South Atlantic Subtropical Surface Water which lies offshore from the western Cape in winter the dominant species are *T. alalunga* and *T. maccoyii*. The occasional finding of *T. albacares* and *T. obesus* in this water mass in winter suggests that a small proportion of these predominantly summer fish do not leave but overwinter at the Cape.

Migrations of South African Tunas

Tunas are known to occur off Angola (Molteno, 1948; Schaefer & Walford, 1950; Vilela & Monteiro, 1959) and Zanzibar (Copley, 1947; Morrow, 1954; Williams, 1956, as well as the south-west Indian ocean (Tsuruta, 1961). Off Angola *T. albacares*, *T. alalunga* and *T. obesus* have been recorded, but no *T. thynnus*, although this species is known from St. Helena Island (Molteno, 1948). *T. albacares* is the dominant species off Zanzibar, together with a few *T. alalunga*, but Williams (pers. comm.) has not recorded *T. obesus* or *T. thynnus*. In the south-west Indian ocean off Durban *T. obesus*, *T. albacares* and *T. ala-*



Fig. 8. World distribution of the three probable species of bluefin tuna *Thunnus thynnus, T. maccoyii and T. orientalis.*

lunga are found (Molteno, 1948; Tsuruta, 1961; and the present survey).

The major annual changes in the tuna populations of the Cape have already been discussed, but which ocean the South African populations are derived from, and what their migrations are in these oceans has always been in doubt. The work of Rivas (1955), Clemens (1961), Hamre (1962) and Mather (1962) have shown that tuna are capable of long migrations at a relatively high average speed (up to 3–5 knots). Mather has shown that *T. thynnus*, of both large and small size, cross the Atlantic. Long distance migrations of albacore across the Pacific have also been shown to occur by the U.S. Fish and Wildlife Service (Otsu & Uchida, 1963).

(*a*) *Thunnus thynnus*

Thunnus thynnus has never been recorded on the Indian ocean side of the Cape, and it seems probable that the small number of this species which occurs off Cape Town during summer have their origin in the Atlantic.

(*b*) *Thunnus maccoyii*

T. maccoyii had never been recorded in the Atlantic until this survey, and is an Indo-Pacific species. The fishes of this species found off the Cape normally have bright yellow peduncle keels, and the only other population of bluefin tuna which is stated in the literature to have this feature occurs in the waters off Australasia (Serventy, 1956*a*). Mimura (1961) described the main fishing areas for this form, off the Australian west coast, mentioning two areas, the 'Old ground' 20°–30°S, 100°–110°E, and the 'New ground' 10°–18°S, 115°–120°E. In addition to these, Laevastu & Rosa (1963) show a third area, 32°–38°S, 80°–95°E, which they state is fished for 'bluefin'. Mimura states that *T. maccoyii* is found only from October to April in the 'New ground', and September to March in the 'Old ground'. It is significant that this is the time during which *T. maccoyii* is absent from the Cape. It is possible that the fish occurring off the Cape may have their origin off the Australian coast. The results of tagging of *T. alalunga* in the north Pacific (Otsu & Uchida, 1963) and of *T. thynnus* in the Atlantic and Pacific (Hamre, 1963; Mather, 1963*a*) have shown that an annual migration of this magnitude is not impossible.

Subsequent to this survey, however, *T. maccoyii* has been found to occur in the south Atlantic at Vema seamount (31° 38′S 8° 20′E) (Penrith (1967) and later personal catches from the R.V. *Thomas B. Davie* belonging to the University of Cape Town), and Shingu (1967) has shown that *T. maccoyii* is found over a wide band of the south temperate zone, but probably avoids the warm water of the Agulhas Current.

(*c*) *Thunnus alalunga*

The distribution of *T. alalunga* around the South African coast shows a strange break in continuity. The species is common off Angola, St. Helena Island, Walvis Bay, Stompneus Bay (outside the Benguela Current), and from

Cape Columbine to Danger Point. The species is then, as far as is known, absent from waters off the South African south-east coast, but reappears off Durban and, although found by Tsurutu (1961) to be present well off the African coast to 35°S, is not plentiful in this area (Kataoka, 1957; Laevastu & Rosa, 1963). It seems therefore very reasonable to assume that the population of *T. alalunga* found off the Cape is of Atlantic origin, and is the south-eastern limit of a large population which is known in the South Atlantic from 10°–35°S, according to Laevastu & Rosa (1963).

(*d*) *Thunnus obesus* and *T. albacares*

The origin of *T. obesus* and *T. albacares* is less clear. The two species are common off Angola and are also found in the south-west Indian ocean off Durban. Mention was made earlier of the extremely large catch of *T. albacares* made at three stations between Cape St. Francis and Cape Recife at the end of August 1960, together with smaller numbers of *T. obesus*. It is felt that these catches were highly significant for two reasons. Firstly, August was approximately one month before the two species began to appear off the Cape Peninsula in the long-line industry catches (Bacon, pers. comm.); and secondly, the large numbers of fish obtained (almost half the *T. albacares* obtained during the entire survey were taken during the three days) suggests a compact migrating population rather than a widespread feeding population. It seems, therefore, in the absence of any valid evidence to suggest an Atlantic origin for *T. albacares* and with it *T. obesus*, that they are probably of Indian ocean origin. The presence of fair numbers of *T. albacares* off Durban in winter and their almost complete absence in summer cannot be explained. It might be speculated that their absence is due to their having migrated southward owing to high temperatures found in the region in summer (similar to the situation off North America, as noted by Radovich, 1961), and that they are actually part of the same population as occurs off the Cape. Alternatively, however, they could have migrated northward to spawn during the summer.

One further point must be discussed in connection with the migration of *T. albacares*. It is common knowledge among Cape anglers that the best catches of *T. albacares* off the Cape Peninsula are made at the beginning and end of the season; during the middle of the season catches in this area tail off somewhat, and at the same time the fish are sometimes found at Mossel Bay. This, in the opinion of Horne (1962) suggests an Atlantic origin for the species. The species is said to come from the Atlantic, reach the Peninsula, then migrate up the east coast to Mossel Bay, and then turn and come back to the Peninsula. If this were true one would expect large numbers of the fish to be caught off Mossel Bay, not the small numbers that are actually found. It is far more likely that large compact migratory schools (such as were found off the east coast during this survey) should reach the Cape (and since they are large and near the surface are easily spotted during trolling) and then break up, so that anglers' catches decline. Some of these fish will feed on the Agulhas Bank, where they often are

seen during summer by trawler crews (Barker, pers. comm.). It is probable that some of these fish enter Mossel Bay. At the end of summer the migratory schools will re-form, and again anglers' catches off the Cape will show a marked increase.

Genetic exchange between Atlantic and Indo-Pacific Tunas

The waters to the south of the Cape are probably the only place where genetic exchange between Atlantic and Indo-Pacific populations of *T. alalunga*, *T. albacares*, and *T. obesus* could take place.

As has been shown, the closely allied *T. thynnus* and *T. maccoyii* occur at the Cape, but these are found at different seasons, and neither breeds in the area.

The other three species, *T. alalunga*, *T. albacares*, and *T. obesus* do not show, in the adult form at least, any great differences between Atlantic and Indo-Pacific populations. This suggests (although does not prove) that there is some genetic interchange between the Atlantic and Indo-Pacific populations. While the migratory patterns discussed above are thought to be the major ones, it is probable that there are smaller migrations of *T. obesus* and *T. albacares* from the Atlantic and *T. alalunga* from the Indian ocean to the Cape, and contact between Atlantic and Indo-Pacific ocean populations takes place.

The possibility of both Atlantic and Indian ocean tunas being present off the Cape in summer, at least, is strengthened by the finding, in the water off the Cape in summer, of marlins which are indigenous to the Indo-Pacific (*Makaira indica* and *Makaira audax*) as well as a marlin known only from the Atlantic (*Tetrapturus albidus*) (Talbot & Penrith, 1962, 1963*b*). The problems of the origin and migration of the Cape tuna population can be elucidated only by the inauguration of a large scale tagging programme on the tunas off the Cape.

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Date	C.P. No.	Bearing	Landmark	Distance Miles	Water Temperature			Salinity OM	Hooks Used	Catch in %				Total	
					OM	30M	150M			LF	YF	BF	BE	No.	%
1960															
16/2	1	W	Slangkop	40	20·40	—	—	—	48	—	—	—	—	—	—
4/3	2	W	Slangkop	43	18·82	16·60	12·18	35·40	60	—	—	—	8·3	5	8·3
5/3	3	W.S.W.	Slangkop	79	20·04	19·82	13·60	35·54	66	7·6	—	—	1·5	6	9·1
6/3	4	W	Slangkop	35	20·04	—	11·03	35·47	66	7·6	—	—	—	5	7·5
7/3	5	W	Danger Point	40	20·38	20·30	9·86	35·46	66	9·4	—	—	—	7	9·4
9/3	6	W	Slangkop	45	20·19	20·19	12·33	35·47	66	7·6	—	—	—	5	7·6
9/3	7	W	Slangkop	45	20·20	20·19	12·35	35·47	66	1·5	1·5	—	—	2	3·0
10/3	8	W.S.W.	Slangkop	75	20·43	20·14	13·96	35·55	66	6·0	1·5	—	—	5	7·6
26/3	9	S	Cape Recife	45	23·80	20·83	11·15	35·37	66	6·0	3·0	—	—	2	3·0
28/3	10	S	Cape Recife	60	18·80	18·62	10·40	35·35	180	—	2·8	—	·5	6	3·3
30/3	11	S	Cape Recife	62	20·40	—	—	—	180	—	3·3	—	—	6	3·3
2/4	12	W	Danger Point	55	19·30	19·29	12·56	35·55	60	5·0	—	—	1·7	4	6·7
27/4	13	W	Slangkop	30	18·24	18·13	15·31	35·53	54	7·1	1·8	1·8	1·8	7	12·5
28/4	14	W	Slangkop	50	18·11	18·09	13·07	35·53	90	1·1	2·2	—	—	3	3·3
30/4	15	W.N.W.	Dassen Island	35	13·83	13·64	11·61	35·06	30	10·0	6·6	3·3	3·3	7	23·4
1/5	16	W.N.W.	Cape Columbine	30	16·66	14·52	10·88	35·38	36	—	—	—	—	—	—
2/5	17	W.N.W.	Cape Columbine	60	15·68	15·23	12·63	35·22	30	—	—	—	—	—	—
3/5	18	W.N.W.	Dassen Island	40	14·85	13·90	11·88	35·17	114	28·0	—	—	—	32	28·0
3/6	19	S.S.W.	Yzervark Point	65	21·98	20·91	14·57	35·47	114	—	—	—	—	—	—
4/6	20	S	Knysna	55	21·04	21·02	11·93	35·48	114	—	—	—	—	—	—
5/6	21	S	Cape St. Francis	25	21·10	19·23	11·11	35·47	42	—	—	—	—	—	—
11/6	22	W	Cape Point	30	17·25	17·21	11·83	35·47	114	6·1	—	2·6	·9	11	9·6
12/6	23	W	Slangkop	45	17·30	17·23	11·64	35·49	36	—	—	13·9	—	5	13·9
13/6	24	W	Slangkop	65	17·36	17·21	13·30	35·48	150	11·3	—	31·3	—	64	42·6
15/7	25	W	Slangkop	50	16·80	—	—	—	36	5·5	—	2·8	—	3	8·3
17/7	26	W	Slangkop	75	16·70	16·30	13·05	35·43	108	6·5	—	2·8	—	10	9·3
18/7	27	W	Slangkop	45	15·58	15·31	12·24	35·43	90	15·5	—	14·5	—	27	30·0
19/7	28	W	Slangkop	30	16·48	16·01	11·97	35·47	54	40·7	—	—	—	22	40·7
20/7	29	N.W.	Cape Columbine	37	15·58	15·50	13·14	35·43	120	—	—	—	—	—	—
21/7	30	W.N.W.	Dassen Island	35	14·48	14·47	9·31	35·26	120	·8	·8	9·2	—	13	10·8
22/7	31	W.N.W.	Table Mountain	45	17·81	17·45	13·24	35·50	120	20·0	·8	24·2	—	54	45·0
28/8	32	S.E.	Cape Infanta	100	18·50	—	—	—	120	—	—	—	—	—	—

Date	C.P. No.	Bearing	Landmark	Distance Miles	Water Temperature			Salinity OM	Hooks Used	Catch in %				Total	
					OM	30M	150M			LF	YF	BF	BE	No.	%
1960															
29/8	33	S.E.	Cape St. Francis	60	19·23	18·98	11·06	35·47	150	—	28·0	—	1·4	44	29·8
31/8	34	S.S.E.	Cape Recife	50	17·95	17·31	11·82	35·42	120	—	15·0	—	·8	19	15·8
1/9	35	S.S.E.	Cape Recife	60	20·15	19·97	16·23	35·44	90	—	22·2	—	4·5	24	26·7
1/10	36	W.N.N.	Dassen Island	35	16·32	16·30	13·96	35·51	114	24·6	—	4·4	—	33	29·0
2/10	37	W.N.W.	Cape Columbine	45	16·48	16·41	13·87	35·53	114	4·4	—	1·8	—	7	6·2
3/10	38	W.N.W.	Cape Columbine	60	16·41	16·38	13·42	35·54	114	13·2	—	—	—	15	13·2
4/10	39	W	Slangkop	45	16·59	16·58	12·52	35·53	114	12·3	—	12·3	·9	29	25·5
5/10	40	W	Slangkop	45	16·70	—	—	—	66	21·2	—	9·1	1·5	21	31·8
6/10	41	W	Slangkop	30	16·70	—	—	—	42	9·5	—	—	4·8	6	14·3
8/10	42	W	Slangkop	55	16·38	16·13	12·21	35·51	150	9·3	—	6·7	—	24	16·0
2/11	43	W	Slangkop	40	18·20	—	—	—	60	1·7	—	—	1·7	2	3·3
3/11	44	W	Slangkop	60	18·14	17·77	—	35·48	120	3·3	—	3·3	·8	9	7·5
3–4/11	45	W	Slangkop	45	18·20	—	—	—	60	1·7	—	1·7	—	2	3·3
4/11	46	W	Slangkop	45	18·02	17·57	13·78	35·54	120	10·8	—	2·5	—	16	13·3
5/11	47	W	Cape Point	30	18·00	—	—	—	90	18·9	5·5	5·5	—	27	30·0
6/11	48	W.N.W.	Danger Point	40	18·59	18·54	12·29	35·50	114	1·8	—	4·4	—	7	6·2
7/11	49	W	Danger Point	50	17·64	17·85	12·29	35·53	120	14·2	—	2·5	1·7	22	18·2
8/11	50	W	Cape Point	40	17·98	17·93	13·01	35·53	120	10·0	—	5·8	·8	20	16·7
9/11	51	W	Cape Point	30	18·10	—	—	—	54	16·7	—	5·6	—	12	22·2
9/11	52	W	Cape Point	30	18·10	—	—	—	72	6·9	4·2	—	—	8	11·1
10/11	53	W	Slangkop	45	18·40	—	—	—	150	4·7	—	1·3	1·3	11	7·3
7/12	54	W	Cape Columbine	30	17·80	—	—	—	120	23·4	—	·8	1·7	31	25·8
8/12	55	W.N.W.	Dassen Island	35	18·10	—	—	—	120	2·5	—	1·7	10·0	17	14·2
9/12	56	W.N.N.	Table Mountain	50	17·80	—	—	—	120	12·5	—	·8	2·5	19	15·8
10/12	57	W	Slangkop	45	20·50	—	—	—	120	5·8	—	—	3·3	11	9·2
10/12	58	W	Slangkop	45	20·50	—	—	—	90	6·6	—	—	3·3	9	9·9
11/12	59	W	Slangkop	60	21·40	—	—	—	120	5·0	—	—	3·3	10	8·3
11/12	60	W	Slangkop	60	21·50	—	—	—	90	11·0	—	—	6·6	16	17·6
12/12	61	W	Hout Bay	18	15·90	—	—	—	120	—	7·5	—	—	9	7·5
1961															
3/1	62	S	Cape Recife	45	21·31	19·39	13·83	35·31	120	—	—	—	1·7	2	1·7
3/1	63	S	Cape Recife	45	21·31	19·39	13·83	35·31	60	—	—	—	3·3	2	3·3

8/1	64	S	Danger Point	40	21·42	21·23	—	35·49	120	5·8	4·2	—	·8	13	10·8
9/1	65	W	Slangkop	45	19·50	—	—	—	120	2·5	·8	—	13·3	20	16·7
9/1	66	W	Slangkop	45	19·60	—	—	—	9	—	1·1	—	7·7	8	8·8
11/3	67	W	Slangkop	15	14·70	—	—	—	—	—	—	—	—	—	—
12/3	68	W	Slangkop	30	19·60	—	—	—	120	2·5	2·5	—	·8	7	5·8
13/3	69	W	Slangkop	45	21·21	21·21	14·49	35·47	120	1·7	·8	—	—	3	2·5
14/3	70	S.W.	Danger Point	55	21·42	21·31	11·87	35·43	120	10·0	15·8	—	—	31	25·8
14/3	71	S.W.	Danger Point	55	21·42	21·31	11·87	35·43	60	1·7	3·3	—	—	3	5·0
15/3	72	W×S	Danger Point	50	21·60	—	—	—	120	—	·8	—	1·7	3	2·5
15/3	73	W×S	Danger Point	50	21·60	—	—	—	60	15·8	—	—	5·0	12	20·8
16/3	74	W	Slangkop	45	21·59	21·54	13·65	35·45	120	2·5	1·7	—	—	5	4·2
16/3	75	W	Slangkop	40	21·59	21·54	13·65	35·45	60	6·7	—	—	—	4	6·7
17/3	76	W.N.W.	Dassen Island	40	19·50	—	—	—	120	17·5	—	—	1·7	23	19·2
17/3	77	W.N.W.	Dassen Island	40	19·40	—	—	—	60	6·7	—	—	—	4	6·7
18/3	78	W.N.W.	Table Mountain	40	15·90	—	—	—	120	5·8	—	—	—	7	5·8
16/4	79	W	Cape Columbine	40	20·64	19·34	12·82	35·56	102	9·8	—	—	—	10	9·8
17/4	80	W	Cape Columbine	60	20·01	18·95	14·37	35·52	120	15·8	·8	3·3	2·5	27	22·5
17/4	81	W	Cape Columbine	60	20·00	18·95	14·37	35·52	60	15·0	—	—	—	9	15·0
18/4	82	W.N.W.	Dassen Island	45	19·80	19·69	14·83	35·52	120	15·0	2·5	—	—	21	17·5
18/4	83	W.N.W.	Dassen Island	45	19·80	19·69	14·83	35·52	60	3·3	3·3	—	—	4	6·6
19/4	84	W	Slangkop	45	19·79	19·75	13·56	35·50	120	40·0	—	—	—	48	40·0
19/4	85	W	Slangkop	45	19·79	19·75	13·56	35·50	60	31·7	—	—	—	19	31·7
20/4	86	W	Slangkop	18	16·23	15·07	11·16	35·44	120	5·0	·8	—	—	7	5·8
20/4	87	W	Slangkop	18	16·23	15·07	11·16	35·44	60	3·3	—	—	—	2	3·3
21/4	88	W	Slangkop	40	19·03	19·01	11·98	35·37	120	19·2	—	—	—	23	19·2
21/4	89	W	Slangkop	40	19·03	19·01	11·98	35·37	60	28·3	1·7	—	—	18	30·0
22/4	90	W	Slangkop	55	18·95	18·92	12·76	35·39	120	15·0	1·7	—	—	20	16·7
23/4	91	W	Slangkop	60	19·25	19·02	12·95	35·46	120	5·8	—	—	—	7	5·8
23/4	92	W	Slangkop	60	19·25	19·02	12·95	35·46	48	20·6	—	—	—	11	20·6
20/5	93	W	Danger Point	40	20·40	—	—	—	120	·8	2·5	—	—	4	3·3
21/5	94	W	Danger Point	55	20·60	—	—	—	120	20·0	5·0	—	—	30	25·0
22/5	95	W	Cape Point	20	19·70	—	—	—	120	25·0	—	—	5·0	36	30·0
23/5	96	W×S	Slangkop	60	20·90	—	—	—	120	25·0	1·7	—	—	32	26·7
24/5	97	W	Slangkop	120	20·53	19·61	14·95	—	120	14·2	·8	—	·8	19	15·8
25/5	98	W×S	Slangkop	20	17·60	—	—	—	120	4·2	—	1·7	1·7	9	7·5
26/5	99	W	Slangkop	45	19·70	—	—	—	120	10·0	·8	—	1·8	14	11·7
21/6	100	W.N.W.	Dassen Island	45	19·10	—	—	—	120	16·7	4·2	13·3	·8	42	35·0

Date	C.P. No.	Bearing	Landmark	Distance Miles	Water Temperature			Salinity OM	Hooks Used	Catch in %				Total	
					OM	30M	150M			LF	YF	BF	BE	No.	%
1961															
22/6	101	W	Cape Columbine	45	19·22	19·21	13·58	—	108	21·3	·9	18·5	·9	45	41·6
23/6	102	W.N.W.	Dassen Island	45	18·99	18·96	13·41	—	108	26·9	—	13·9	—	44	40·8
24/6	103	W	Slangkop	35	18·30	—	—	—	108	22·2	—	—	—	24	22·2
25/6	104	W×N	Slangkop	40	17·80	—	—	—	108	10·2	—	—	—	11	10·2
26/6	105	S.W.	Cape Point	40	17·94	17·86	12·43	—	102	19·6	—	3·9	—	24	23·5
28/8	106	W	Cape Columbine	45	15·90	—	—	—	84	11·9	—	7·1	—	16	19·1
29/8	107	S.W.	Cape Columbine	50	16·19	16·12	13·40	—	84	9·5	—	13·1	—	19	22·6
30/8	108	W.N.W.	Dassen Island	40	16·20	—	—	—	84	4·8	—	1·2	—	5	6·0
2/9	109	W	Slangkop	30	16·40	—	—	—	84	9·5	—	15·5	2·4	23	27·4
3/9	110	W.S.W.	Slangkop	25	15·80	—	—	—	78	9·0	—	1·3	1·3	9	11·6
5/9	111	W×S	Slangkop	20	15·80	—	—	—	66	13·6	—	1·5	1·5	11	16·7

Appendix A (i)

Summary of stations occupied by m/t *Cape Point* during the tuna survey off the south and west Cape coast 1960–61.
L.F. = *T. alalunga;* Y.F. = *T. albacares;* B.F. = *Thunnus maccoyii;* B.E. = *T. obesus*
The bearings given are the course steered by the vessel from the landmark.
Only tuna are listed in the catch, other fish (sharks, billfish, etc.) are not recorded.
Positions of the landmarks listed are:

	S	E		S	E
Slangkop lighthouse . .	34° 09′	18° 19′	Knysna Heads	34° 05′	23° 04′
Danger Point lighthouse .	34° 38′	19° 18′	Cape St. Francis lighthouse . .	34° 13′	24° 50′
Cape Recife lighthouse .	34° 02′	25° 42′	Cape Point lighthouse . . .	34° 21′	18° 30′
Dassen Island lighthouse .	33° 26′	18° 05′	Table Mountain (Maclear's Beacon)	33° 58′	18° 25′
Cape Columbine lighthouse	32° 49′	17° 50′	Hout Bay (Duiker Point) . .	34° 02′	18° 18′
Yzervark Point . . .	34° 23′	21° 44′			

Date	Station LLN	Position S	Position E	Watertemp. Surface	Hooks	Catch in % LF	Catch in % YF	Catch in % BE	Total	
1962										
11/8	1	32° 03′	32° 49′	21·1	120	4·2	5·0	—	11	9·2
12/8	2	32° 30′	35° 16′	20·1	120	3·3	·8	—	5	4·1
15/8	3	31° 58′	43° 45′	18·0	120	·8	1·7	—	3	2·5
15/8	3(a)	31° 58′	43° 45′	18·0	120	—	—	—	—	—
18/8	4	26° 44′	44° 19′	22·7	120	—	—	—	—	—
19/8	5	26° 24′	40° 44′	22·8	120	—	—	—	—	—
19–20/8	6	25° 56′	39° 31′	23·1	120	—	—	—	—	—
21–22/8	7	26° 25′	33° 44′	23·0	120	—	—	—	—	—
23/8	8	30° 00′	31° 42′	21·9	120	—	9·2	—	11	9·2
23/8	8(a)	30° 00′	31° 42′	21·9	120	3·3	8·3	—	14	11·9
1963										
15/2	9	32° 06′	35° 25′	20·0	120	—	·8	—	1	·8
19/2	10	31° 50′	44° 11′	24·0	120	—	—	·8	1	·8
21/2	11	27° 10′	45° 45′	26·1	120	—	—	—	—	—
22/2	12	26° 56′	42° 11′	26·3	120	—	—	—	—	—
25/2	13	26° 42′	35° 00′	27·3	120	—	—	—	—	—
26/2	14	29° 46′	32° 25′	26·2	120	—	·8	—	1	·8
26/2	14(a)	29° 46′	32° 25′	26·2	120	—	—	—	—	—

Appendix A (ii)

Summary of stations occupied by S.A.S. *Natal* during the tuna survey in the south west Indian Ocean. 1962–63.